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LEAKAGE CURRENT MEASUREMENTS IN SOI DEVICES

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13. ABSTRACT (Maximum 200 words)
Total dose response of both NMOS and PMOS FETs fabrication on SOI substrates were studied. Back channel leakage currents were studied. Two types of SOI substrates were chosen to study back channel leakage currents: SIMOX and ZMR. Subthreshold current-voltage characteristics as a function of total dose of the back channel and front channel of SIMOX and ZMR SOI substrates are reported. Some preliminary reports on the buried oxide leakage current are also provided.

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1 INTRODUCTION

We have studied the total dose response of both n-MOS and p-MOS FET's fabricated on SOI substrates. In particular we have performed detailed measurements on both the channel and oxide leakage currents for different levels of dosages. Two different types of SOI MOSFET's are studied: (i) SIMOX and (ii) ZMR which are fabricated by ion implantation and zone melt recrystalization respectively. The differences in the total dose response will be reported. In the next section we will describe the structure of the devices that we studied, in section three we shall outline the experiments performed and in section four we will discuss the results, in section five we shall state our conclusions based on the experimental results and in section six we will discuss the future works.

2 THE DEVICES

The structure of the device is shown in fig. 1, in which the device has a characteristic "H" shaped gate region. Also, there is provisions for making electrical contacts with the body. The details of the device parameters are listed in the table below:

STRUCTURE	SIMOX	ZMR
W/L (μm)	31.2/3.6, 1.2 7.2/1.2, H	45/3, H
Buried Oxide Thickness (nm)	25	36.5
Oxygen dose cm^{-2}	1.4×10^{18}	NA
Anneal Time (Hrs)	4-10	NA
Si Thickness (nm)	280	300
Epi layer	Yes	- Yes

3 EXPERIMENTS

The experimental set up is indicated in fig. 2. The device under test (DUT) was place inside a shielded box for testing after being irradiated in Co-60 radiation cell building a total dose of different levels of irradiation. The time lapse between the irradiation and testing is typically about 30 minutes. The biasing conditions of the devices during irradiation is shown in the table 2 as indicated below:

TERMINAL	N-CHANNEL	P-CHANNEL
V_G	5V	5V
V_S	Com	5V
V_D	Com	Com
V_{G1}	-5V	-5V
Body	NC	NC

where V_G, V_S, V_D, V_{G1}, are the front gate, source, drain, and back gate biases respectively. We have measured the subthreshold I-V characteristics of both the front and back channels as a function of the total dose, and the typical results are shown in figures 3 and 4. Similar leakage current measurements were conducted with the ZMR devices and the results are shown in figures 5 and 6.

Besides measuring the leakage currents along the front and back channels of the transistors we have also studied the leakage currents through both the front and back gate oxides. In both cases the gate is biased with a dc voltage and the resulting current through the oxide is measured using the HP4140B picoammeter. The devices are housed inside a shielded box to eliminate extraneous noise since the currents are typically of the order 10^{-12}A or less. Two different techniques are utilized for measuring the I-V characteristics:

1. The currents are measured at a delay of greater than 30 seconds after the gate voltages have be set. The reason for this is that transient currents with long time constants. of approximately 15sec, were observed. The transient current with respect to time immediately after a step voltage is set is shown in figure 7. The I-V characteristics

through the gate oxides with measurements made after the time delay for both top and buried oxides are shown in figures 8 and 9. The last digit of the codes for the different curves indicate the radiation dosage of the devices as indicated below

0 pre-irradiaiton sample

3 50 krads

4 100 krads

5 200 krads

7 750 krads

2. I-V characteristics with no time delay are shown in figures 10 - 12.

We have performed C-V measurements for different radiation dosages. The C-V measurements were typically performed at 1 MHz as shown in fig. 13. The low frequency C-V characteristics inferred from the I-V curves are shown in fig. 14

4 EXPERIMENTAL RESULTS AND DISCUSSIONS

From the experimental results presented in the last section it is observed that the leakage current, both along and through the gate oxides, changes with the levels of irradiation. The changes can be generally explained by the increase in the oxide charge, Q_{ox}, as well as the $Si - SiO_2$ interface states, D_{it}.

The increase in the oxide charge, Q_{ox}, is supported by the shift in the high frequency C-V curves as indicated in fig. 13. Similar conclusions can be made with the low frequency C-V curves in fig. 14. Also, the increase in the subthreshold leakage currents along the conduction channel, both are due to changes in the threshold voltage as a result in the increment in Q_{ox}. From the direction of the shift in the threshold voltages, indicated in the C-V curves as well as in the subthreshold leakage currents, Q_{ox} is found to be positively charged. However, from these measurements alone we are not able to determine whether neutral localized states are also formed within the oxide.

The long delay I-V characteristics through the oxides also supports the increase in the localized states in the oxide. We believe this leakage current is due to carriers hopping between localized states in the oxide. When the oxides are irradiated, more localized states are formed thus increasing the transition rates of the hopping process as the average distance of hops is reduced. This results in the increase in the conductance of the oxide as most clearly observed in figs. 8 and 9. However, more worked is needed in order to achieve a detailed quantitative understanding of the process and to explain the bounce back phenomenon observed in some of the devices.

The increase in D_{it} can be seen from the low frequency C-V measurements in which on top of a shift in the threshold voltage changes in the shape of the C-V curves are apparent where bumps are observed. This is interpreted as the increase in surface states. This effect can also be studied by analyzing the noise characteristics and its dependence on gamma rays irradiation.

5 CONCLUSIONS

We have shown that gamma rays irradiation causes an increase in both the oxide charges and interface states. This results in an observed shift in the threshold voltage leading to an increase in the subthreshold leakage current parallel to the gate area. However, another type of leakage current that conducts through the oxide suggests an increase in the density of localized states in the oxide with gamma rays irradiation. These states can be neutral or charged, for this reason the threshold voltage shifts and subthreshold leakage alone are not able to completely characterize the effects of gamma irradiation.

6 REMARKS ON FUTURE WORK

More work is needed to characterized the leakage current through the oxide. This includes an fundamental understanding of the mechanisms of the leakage current. Specifically, by measuring the variation of the conductance of the oxide film with temperature as well as radiation dosage we will be able to confirm whether a hopping mechanism is involved. These measurements will also enable us to measure the activation energies involved and the mean

distance of the hops. These information are valuable in the understanding of the total effects radiation on the quality of the oxide films as well as a quantitative measure of the increase in the localized states within the gate oxides. We also suggest a study of the dependance of the device noise with radiation dosages. This is particularly important for analog applications, also it has long been known that low frequency excess noise is a powerful technique for characterizing the density of interface states at the $Si - SiO_2$ interface particularly at the energy ranges outside the capability of traditional C-V measurements.

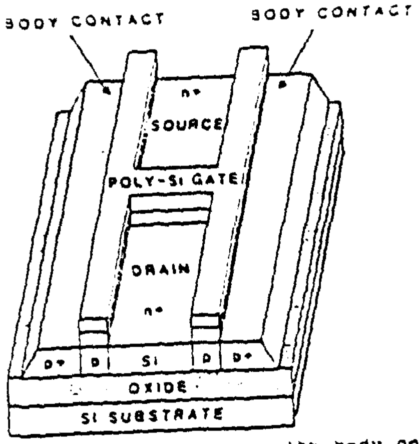


Fig. 1. A MOSFET structure with body contact on SOI substrate.

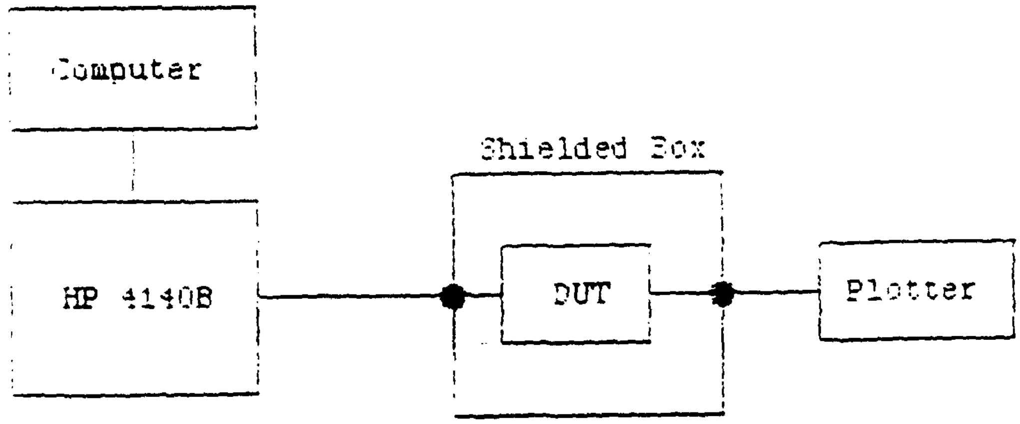


fig. 2

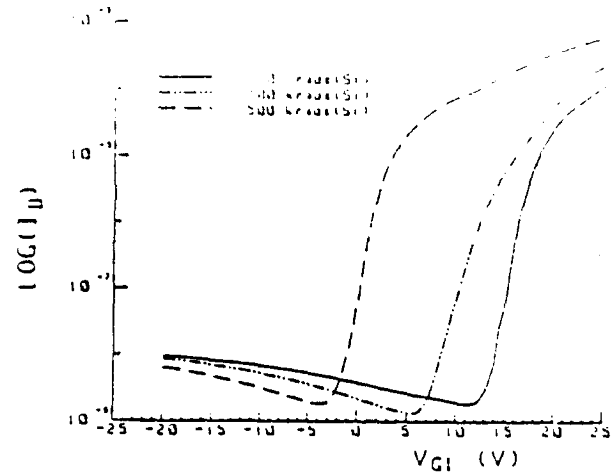


Fig. 3 Subthreshold I_D-V_{G1} characteristics of the back channel of a 1.2 um SIMOX NMOS with V_{G1} = -5 V and V_D = 5 V as a function of total dose.

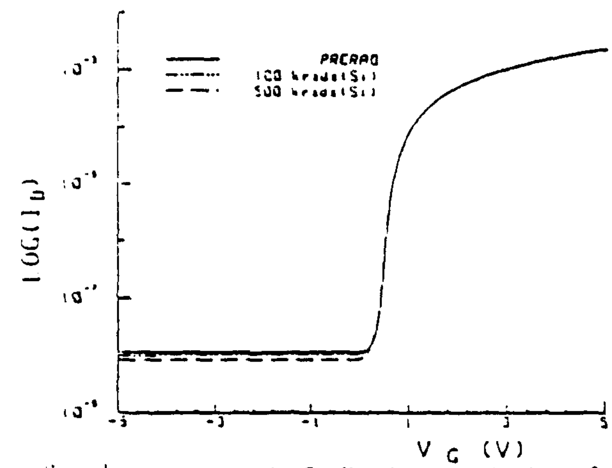


Fig. 4 Subthreshold I_D-V_G characteristics of the front channel of a 1.2 um SIMOX NMOS with V_{G1} = -20 V and V_D = 5 V as a function of total dose.

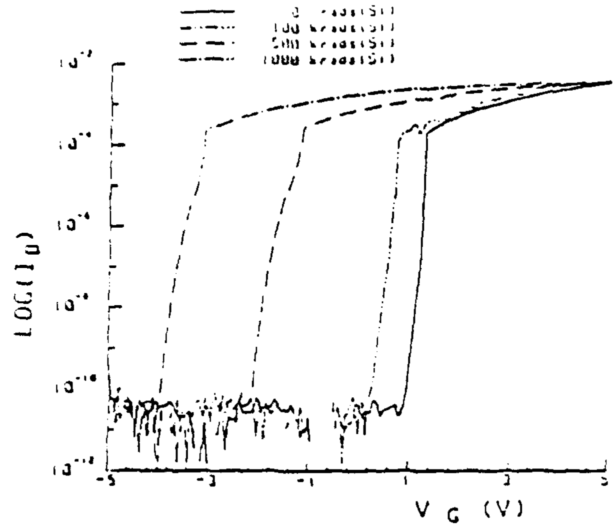


Fig. 5 Subthreshold I_D-V_G characteristics of the front channel of a 3 um ZMR NMOS with V_{G1} = -20 V and V_D = 3 V as a function of total dose.

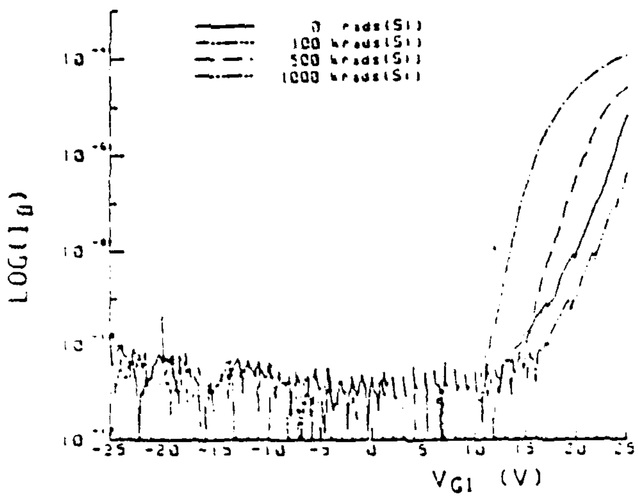


Fig. 6 Subthreshold I_D-V_{G1} characteristics of the back channel of a 3 um ZMR NMOS with V_{G1} = -20 V and V_D = 3 V as a function of total dose.

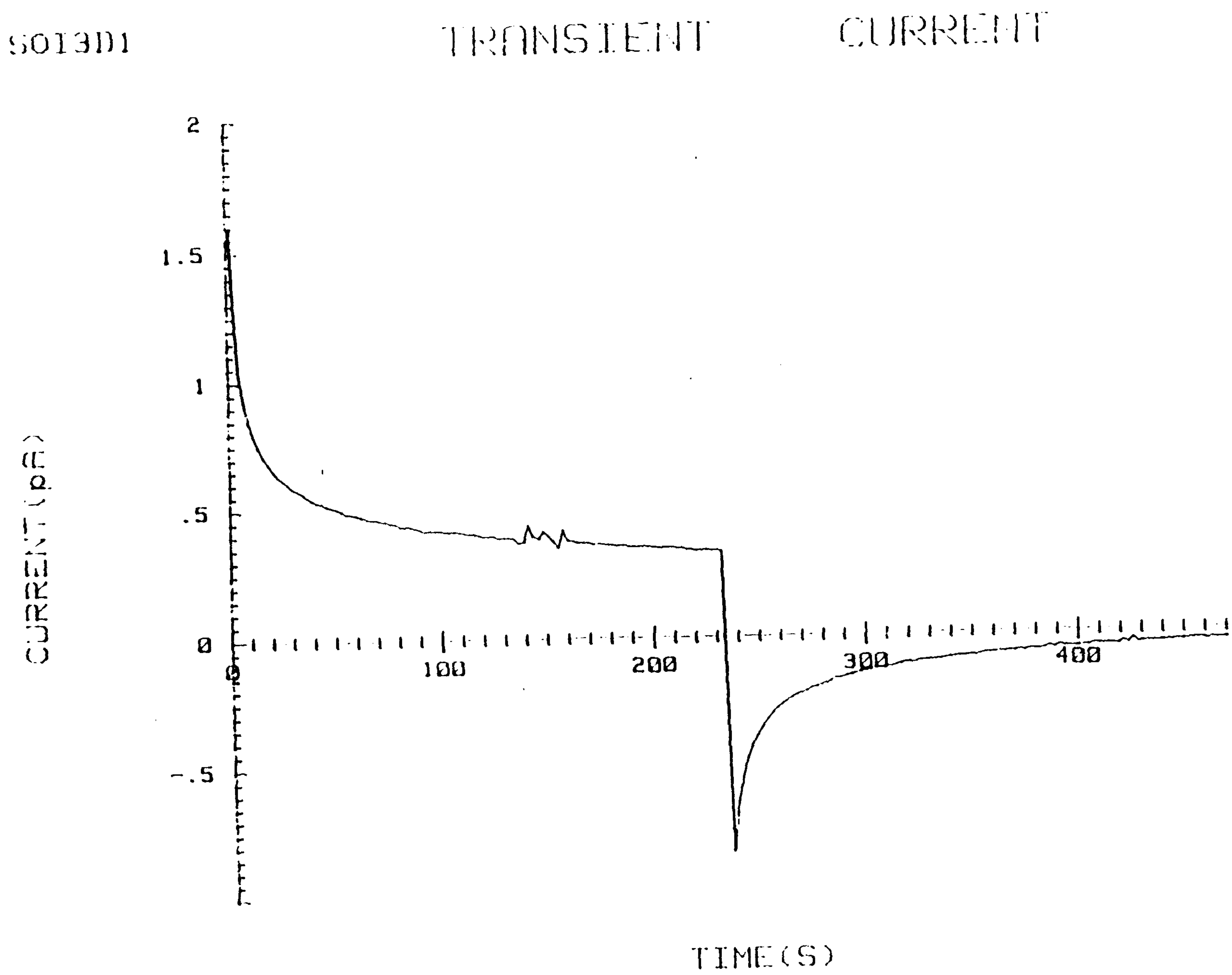
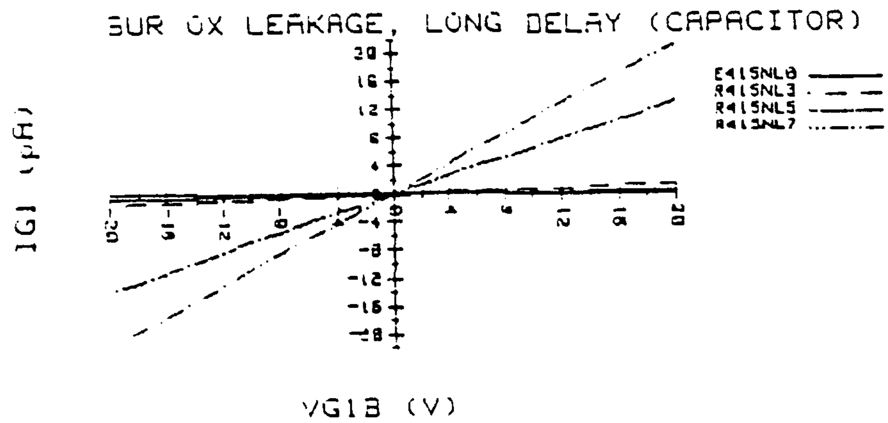
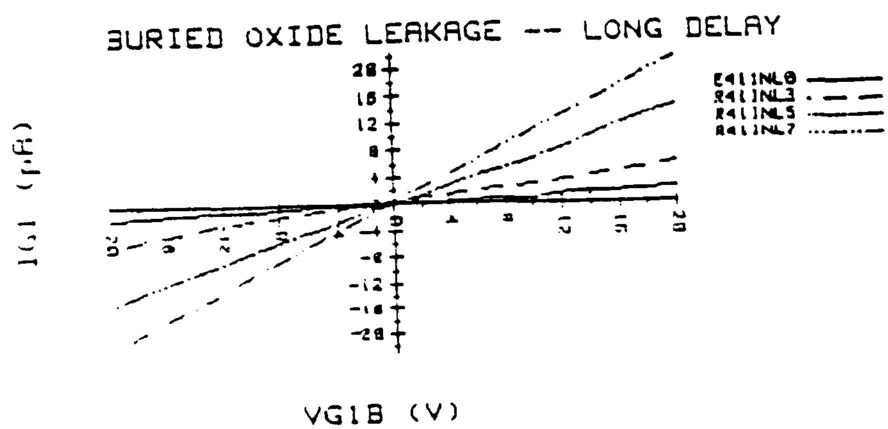

SOI3D1
TRANSIENT CURRENT
CURRENT (pA)
2
1.5
1
.5
0
-.5
0
100
200
300
400
TIME (S)

fig. 7



BUR OX LEAKAGE, LONG DELAY (CAPACITOR)
E415NL0
R415NL3
R415NL5
R415NL7
IG1 (μA)
VG1B (V)

fig. 8



BURIED OXIDE LEAKAGE -- LONG DELAY
E411NL0
R411NL3
R411NL5
R411NL7
IG1 (μA)
VG1B (V)

fig. 9

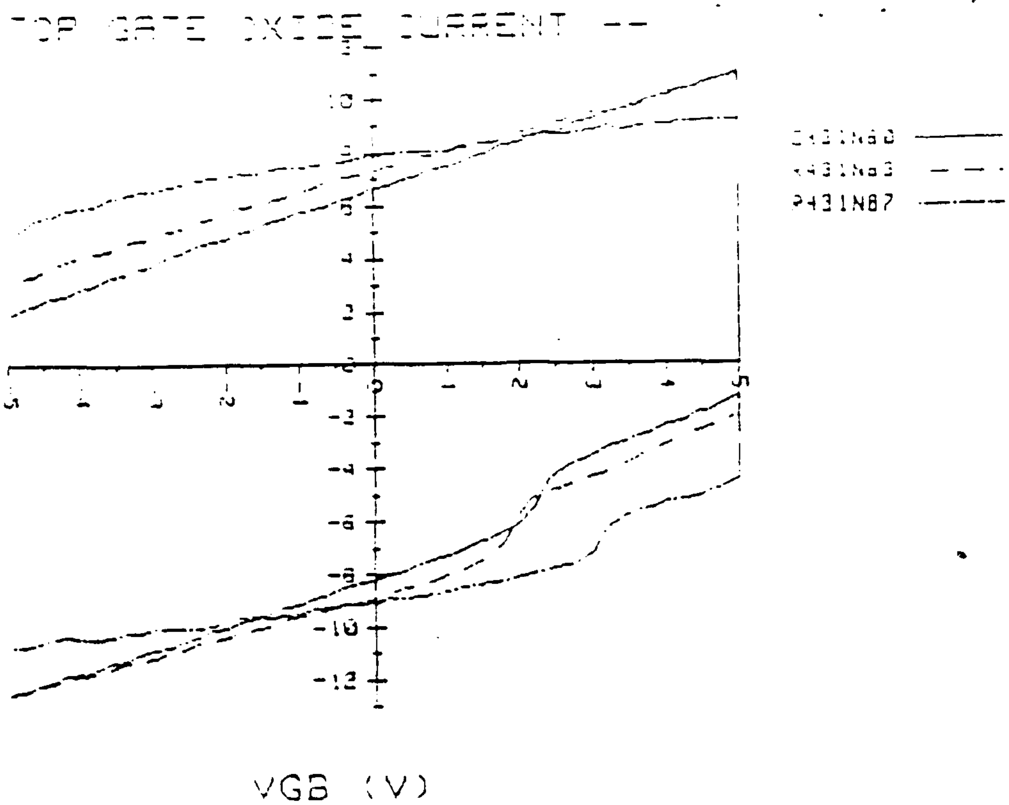

TOP GATE OXIDE CURRENT --
P431N87
VGB (V)

fig. 10

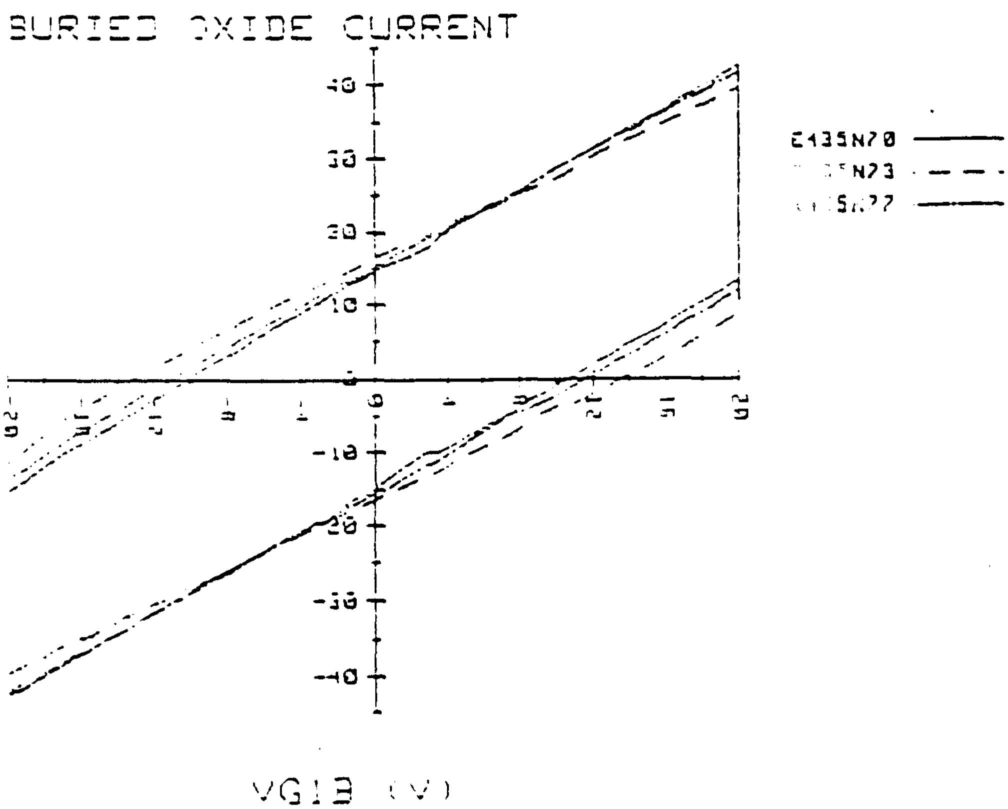

BURIED OXIDE CURRENT
E435N70
VG1B (V)

fig. 11

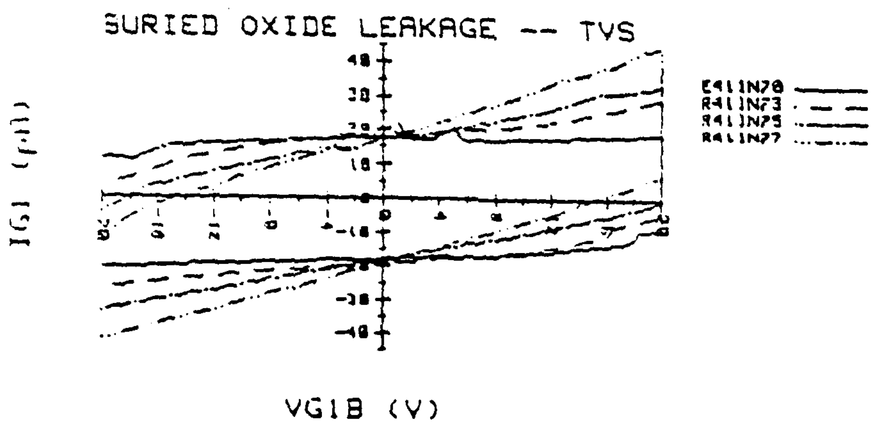


fig. 12

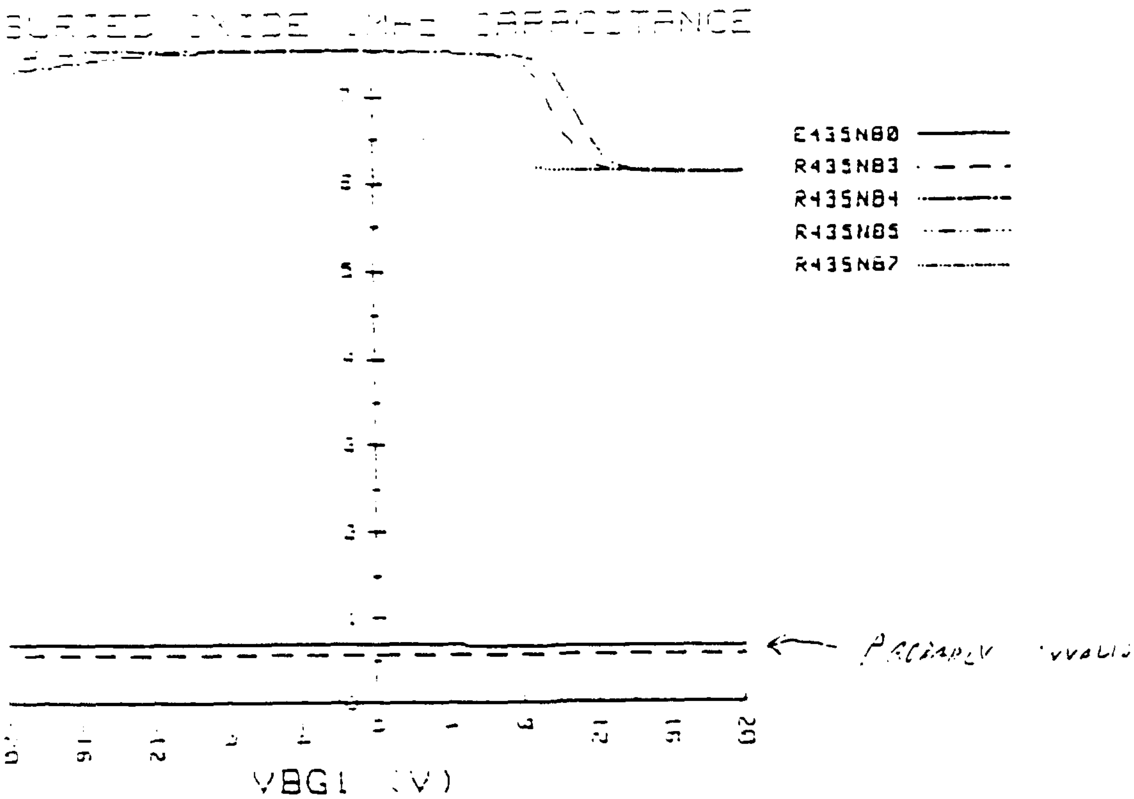

E435N80
R435N83
R435N84
R435N85
R435N87
VBG1 (V)

fig. 13

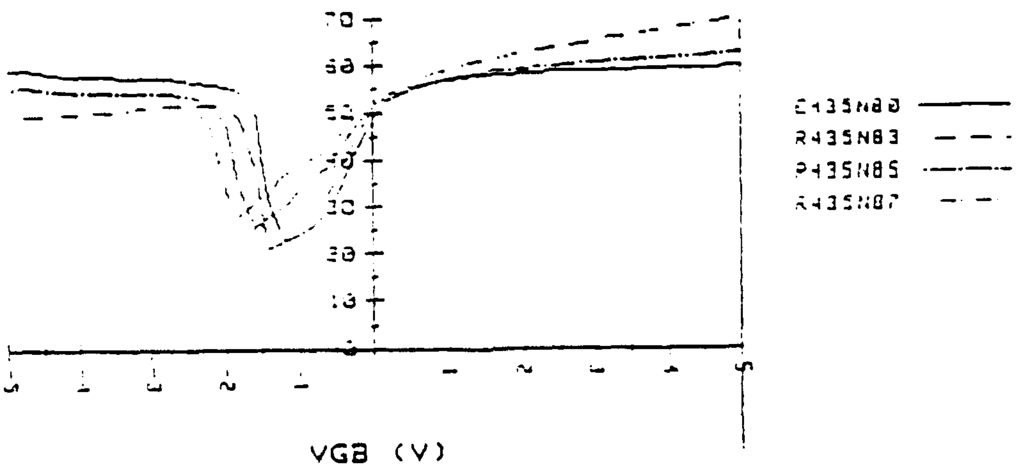

E435N80
R435N83
R435N85
R435N87
VGB (V)

fig. 14

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